ERDC/CHL CHETN-VII-7
September 2006

US Army Corps of Engineers®

Application of the SAM Computer Program for Truckee River Stable Channel Analysis

by Stephen H. Scott

PURPOSE: The purpose of this Coastal and Hydraulics Engineering Technical Note (CHETN) is to demonstrate the utility of the SAM computer programs for evaluating the stability of a stream restoration design on the Truckee River. SAM is an integrated system of computer programs developed under the Flood Damage Reduction and Stream Restoration Research Program sponsored by the U.S. Army Corps of Engineers (USACE 2000). These programs are designed to satisfy the need for an easy-to-use methodology for use in preliminary screening of alternatives. It is intended to be used primarily as an aid in the design of stable channels.

The SAM package enables the user to evaluate the hydraulics, sediment transport, and sediment yield for representative stream cross sections. The programs are not considered to be a model in the sense of evaluating the hydraulics and sediment transport characteristics of an entire stream reach. The sediment transport algorithms in SAM do not compute bed elevation change (erosion and deposition), only sediment transport capacity based on computed hydraulics.

For this example, the SAM programs are applied to the Truckee River near Reno, NV. The Truckee River flows from its source, Lake Tahoe, to Pyramid Lake, over a distance of approximately 100 miles. The example restoration reach is located approximately 11 miles downstream of Reno and has a length of approximately 5 miles. The existing channel in this area is characterized by a predominantly gravel and cobble bed, with a slope of approximately 0.0017. The channel bank full widths generally vary from 100-300 ft. Flood-control practices (channel straightening activities) have changed the channel from a meandering plan form to a relatively straight reach. These efforts combined with resulting bed degradation (deepening of the channel invert) have resulted in less frequent overbank flows.

The goal of the restoration effort is to increase the frequency of overbank flows by restoring the channel meander through channel realignment and reducing the channel cross-sectional area and slope. Over time, it is anticipated that the channel will resume a more natural meander pattern in the floodplain, with increased overbank flows encouraging growth of native vegetation and recharging adjacent wetlands.

In a stable (or dynamic equilibrium) condition, a river has adjusted its width, depth, and slope so there is no channel aggradation, degradation, or changes in planform, meander, or sinuosity. Although the study reach in question has been realigned in the past, it appears to currently be relatively stable, with no apparent evidence of excessive sediment deposits in the channel or features such as bank failure and retreat that signify a degrading channel.

If channel modifications are introduced, such as decreasing the channel cross-sectional area and reducing the slope, channel instability may result as the channel strives to return back to the original state of equilibrium. A qualitative relationship was developed to illustrate the concept of channel

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **SEP 2006**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Application of the SAM Computer Progoram for Truckee River Stable Channel Analysis**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Engineer Research and Development Center Vicksburg, MS 39180**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**14**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

equilibrium (Lane 1955). This proportionality relationship is defined by four variables: water discharge (Q), slope (S), sediment discharge (Q_s), and sediment size (D_{50}):

$$QS \alpha Q_s D_{50}$$

For the case of the Truckee River restoration effort, decreasing the slope with a constant discharge and sediment size will result in a proportional decrease in sediment discharge. Decreasing the channel cross-sectional area will result in a lower percentage of flow in the main channel, also resulting in a decrease in sediment discharge. Thus, a qualitative inspection of the proposed changes indicates that the restoration channel will be depositional in nature.

The following sections of this CHETN will quantify these changes using the SAM suite of programs and provide guidance on how to use the programs to evaluate stable channel design.

BACKGROUND: The SAM program consists of four modules for use in analyzing channel hydraulics, sediment transport, stable channel design, and sediment yield. Each one of these modules is described in the following sections.

SAM Hydraulics. The SAM hydraulics module computes normal depth (steady uniform flow) and composite hydraulic parameters for a single cross section with variable roughness. A choice of roughness predictors is available. The input data required are discharge, slope, channel cross section geometry, roughness values for the bed, banks, and overbanks, and method of compositing the hydraulic parameters. The geometry can be input in as either a simple trapezoidal channel or by individual station and elevation points.

The output from this module consists of data such as distributed discharge, flow area, wetted perimeter, hydraulic radius, average velocity, composited roughness, and grain bed shear stress. If the flow distribution print option is chosen, these variables are computed and printed for each section of the cross section between the input station and elevation points.

SAM Sediment Transport. The SAM sediment transport module computes the sediment rating curve for individual sediment size classes based on the hydraulic parameters computed in the SAM hydraulics module and the bed sediment size distribution. Twenty sediment transport functions are available for use in the model, with applicability ranging from fine to coarse sand and gravels. A module called SAM AID is available to assist the user with selecting the most applicable function for his application. The hydraulics module will automatically compute a sediment transport input file for use in this module. This input file consists of effective hydraulic sediment transport parameters such as top width, depth, velocity, and energy slope. Additionally, the user must input in the sediment size distribution (percent finer versus sediment size). These parameters are passed to the transport functions to compute the transport capacity of each sediment size class in tons per day and concentration in milligrams per liter.

SAM Sediment Yield. The sediment yield module integrates the flow duration curve with the sediment rating curve to compute the total sediment yield over a given time frame. The input parameters into this module include the sediment rating curve (discharge versus sediment concentration in mg/L) and the flow duration curve. The output of the module gives the total yield of sediment through the cross section in tons per day or cubic yards.

SAM Stable Channel Design. The SAM stable channel design module was developed to provide the capability to calculate stable channel dimensions - channel width, depth, and slope – for a prescribed discharge and sediment load. The output allows the designer to choose from a family of solutions to meet project constraints. Two reach conditions are required. First the sediment load must be computed for an upstream supply reach. This is a representative channel cross section upstream of the new channel design. Then the new channel dimensions and roughness are specified. Only a simple trapezoidal channel without overbanks can be analyzed in the stable channel design module.

Although the objective of this study is to evaluate if the channel restoration design of the Truckee River has stable channel dimensions, this module cannot be directly used for the calculations. The Truckee River bed sediments consist of gravel and cobbles with a median diameter of approximately 60 mm which can be classified as a very coarse gravel. The current version of the stable channel design module in SAM only has two sediment transport functions available: Brownlee for sand transport and the Meyer Peter Muller (MPH) D50 function for gravel transport. The MPH D50 function is not applicable for the Truckee River sediments size distribution. Instead of using the stable channel design module, the change in channel transport capacity from the existing representative channel cross section to the proposed new channel design was evaluated. The analysis procedure was as follows:

a. Compute the return flood flows for the Truckee River at the Reno gauge (2-, 5-, 10-, 25-, 50-, and 100-year return flood).

b. Select a representative channel cross section for the existing river reach.

c. Construct a cross section representing both a narrow and wide stream corridor for both the existing and design cross sections.

d. Compute the hydraulic parameters based on the return flows for each cross section considering only the flow above the movable bed.

e. Compute sediment rating curves for each cross section using three different gravel-based transport functions: Meyer Peter Muller, Parker, and Schoklitsch.

f. Compare the transport capacity between the existing and design cross sections for both narrow and wide stream corridors.

g. Compute the flow duration curve for the Truckee River at the Reno gauge (probability of flow exceeded versus discharge).

h. Compute the sediment yield by integrating the flow duration curve with the sediment rating curve using all three transport functions.

i. Compare the transport capacity and sediment yield for the existing and design cross sections.

ANALYSIS PROCEDURES: The SAM programs were used to compute transport capacity and yield for the existing and design channels. Channel stability can be inferred from these computations. This type of analysis is to be interpreted in terms of relative results between differing channel geometries instead of quantitative results.

Characteristics of Existing and Design Cross Sections. The return flood flows were calculated for the Truckee River at the Reno gauge using a log-Pearson type III distribution (Table 1). A Hydraulic Engineering Center – River Analysis System (HEC-RAS) model of the middle Truckee River was obtained from both the HEC and the U.S. Army Engineer District, Sacramento. Existing cross sections in the restoration reach were evaluated along with cross sections just upstream of the reach. From these cross sections, an average representative cross section was determined. The approximate cross section geometry consisted of a top width of 150 ft, a bottom width of 109 ft and a depth from top bank of 8 ft. The channel roughness as indicated in the HEC-RAS models was 0.039 Manning's n with an average reach slope of 0.0017.

Table 1
Return Flows for Truckee River – Reno Gauge

Return Years	Return Flow, cfs
2	3,076
5	6,396
10	9,243
25	13,551
50	17,248
100	21,334

The restoration reach cross section geometry consists of a top width of 120 ft, a bottom width of 95 ft, and a depth from top bank of 5 ft. A channel roughness of 0.039 was also assumed for the design channel. The average slope was assumed to be 0.0016. Backwater computations with the HEC-RAS model indicate a bank-full discharge of approximately 6,000 cfs for the existing channel reach (5-year return flood) and 3,000 cfs for the design channel (2-year return flood). A narrow and wide stream corridor was assumed for both the existing and design cross sections. The roughness for the overbank was assumed to be 0.06. The channel geometry characteristics are presented in Table 2.

Table 2
Existing and Restoration Design Cross Section Geometry

Condition	Sideslope	Base Width, ft	Top Width, ft	Bankfull Discharge, cfs	Slope
Existing	1V 2.5 H	109	150	6,000	.0017
	1V 2.5 H	109	150	6,000	.0017
Design	1V 2.5 H	95	120	3,000	.0016
	1V 2.5 H	95	120	3,000	.0016

Computation of Hydraulic Geometry. Hydraulic geometry was generated for each cross section using the SAM hydraulics module with the computed return flows. Only data above the movable bed were used for the analysis. The movable bed width for the existing and design channel is assumed to be 150 ft and 120 ft respectively (base width plus banks). The data are presented in Tables 3-6 for four channel geometries: the existing channel with a narrow stream corridor (~750 ft), the existing channel with a wide stream corridor (~1,250 ft), the design channel with a narrow stream corridor, and the design channel with a wide stream corridor.

Table 3
Hydraulic Geometry for Existing Narrow Stream Corridor Channel – Above Movable Bed Only

Q, cfs	% Q	Flow Area, sq ft	Hydraulic Radius, ft	Average Velocity, ft/sec	Grain Shear Stress, lb/sq ft
3,075	100	665	4.8	4.6	0.51
6,396	99.99	1,068	7.0	6.0	0.74
9,243	98.72	1,336	8.7	6.8	0.92
13,551	94.21	1,638	10.7	7.8	1.14
17,248	89.97	1,846	12.1	8.4	1.28
21,334	85.65	2,039	13.3	9.0	1.41

Table 4
Hydraulic Geometry for Existing Wide Stream Corridor Channel – Above Movable Bed Only

Q, cfs	% Q	Flow Area, sq ft	Hydraulic Radius, ft	Average Velocity, ft/sec	Grain Shear Stress, lb/sq ft
3,075	100	665	4.8	4.6	0.51
6,396	99.70	1,067	7.0	6.0	0.74
9,243	94.79	1,299	8.5	6.7	0.90
13,551	82.48	1,510	9.9	7.4	1.05
17,248	73.40	1,630	10.7	7.8	1.14
21,334	66.20	1,743	11.4	8.1	1.21

Table 5
Hydraulic Geometry for Design Narrow Stream Corridor Channel – Above Movable Bed Only

Q, cfs	% Q	Flow Area, sq ft	Hydraulic Radius, ft	Average Velocity, ft/sec	Grain Shear Stress, lb/sq ft
3,075	99.56	645	5.3	4.8	0.53
6,396	91.65	959	7.9	6.1	0.79
9,243	84.76	1,144	9.4	6.8	0.94
13,551	76.76	1,358	11.1	7.7	1.11
17,248	71.57	1,506	12.3	8.2	1.23
21,334	67.05	1,646	13.5	8.7	1.34

Table 6
Hydraulic Geometry for Design Wide Stream Corridor Channel – Above Movable Bed Only

Q, cfs	% Q	Flow Area, sq ft	Hydraulic Radius, ft	Average Velocity, ft/sec	Grain Shear Stress, lb/sq ft
3,075	97.88	638	5.2	4.7	0.52
6,396	76.90	862	7.1	5.7	0.71
9,243	64.10	965	7.9	6.1	0.79
13,551	52.86	1,083	8.9	6.6	0.89
17,248	47.08	1,169	9.6	7.0	0.96
21,334	42.71	1,253	10.3	7.3	1.03

The data indicate that the percentage of flow above the movable bed is higher for the existing channel, resulting in higher velocities and bed shear stress. The percentage of flow above the bed is less in both the existing and design wide stream corridor channel due to overbank storage. The water surface elevations for each discharge are plotted on the cross sections in Figures 1-4. The depth, channel width, velocity, and energy slope were taken for each case and used for input into the SAM sediment transport module to compute the sediment rating curves. The following sediment transport and sediment yield analysis assumes that sediment transport only occurs within the movable bed boundary.

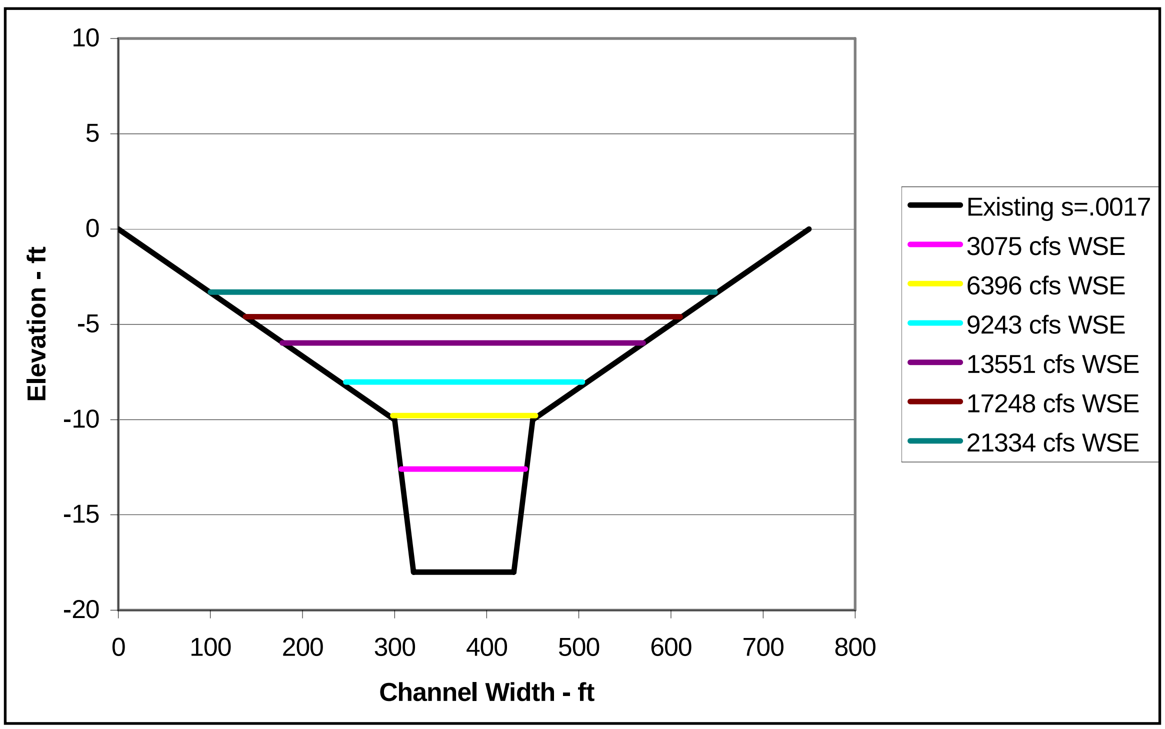

Figure 1. Water-surface elevations in existing channel with a narrow stream corridor

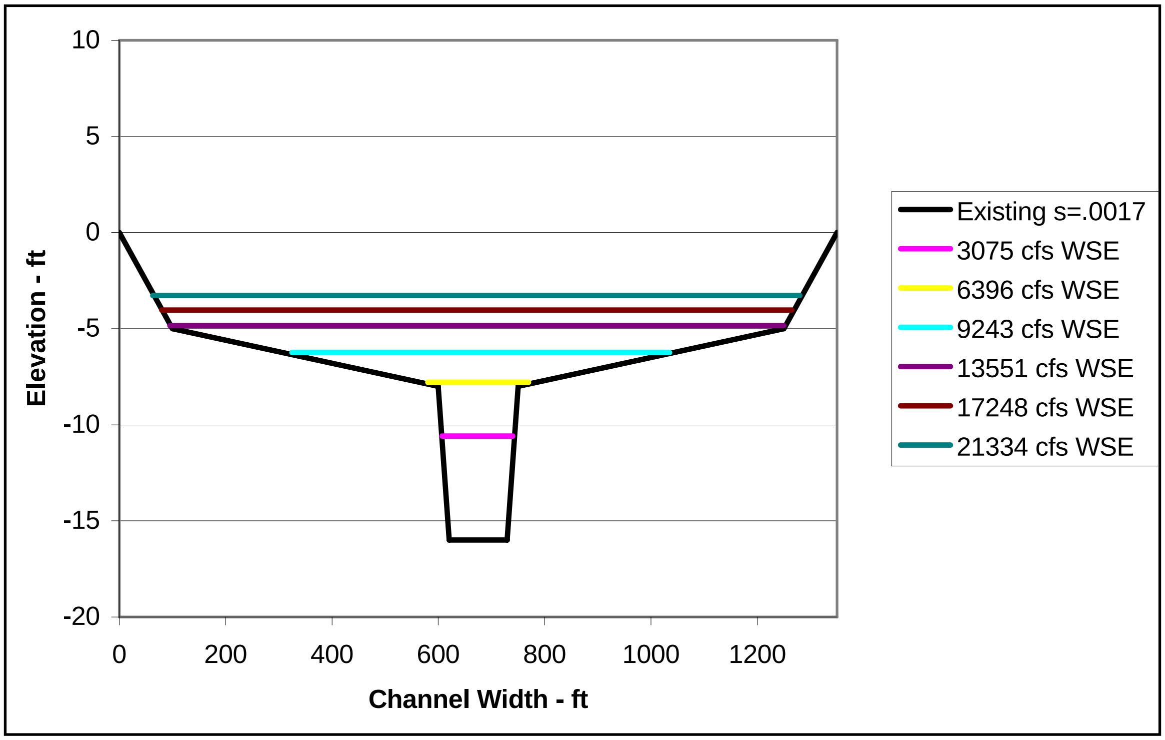

Figure 2. Water-surface elevations in existing channel with a wide stream corridor

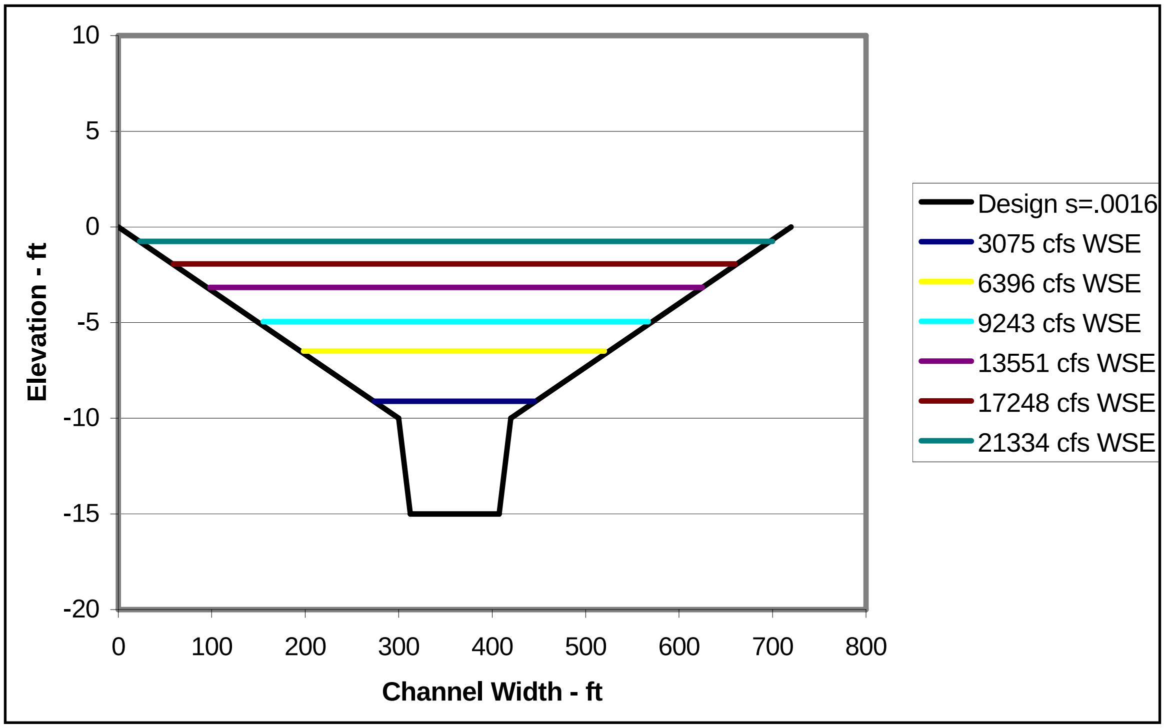

Figure 3. Water-surface elevations in design channel with a narrow stream corridor

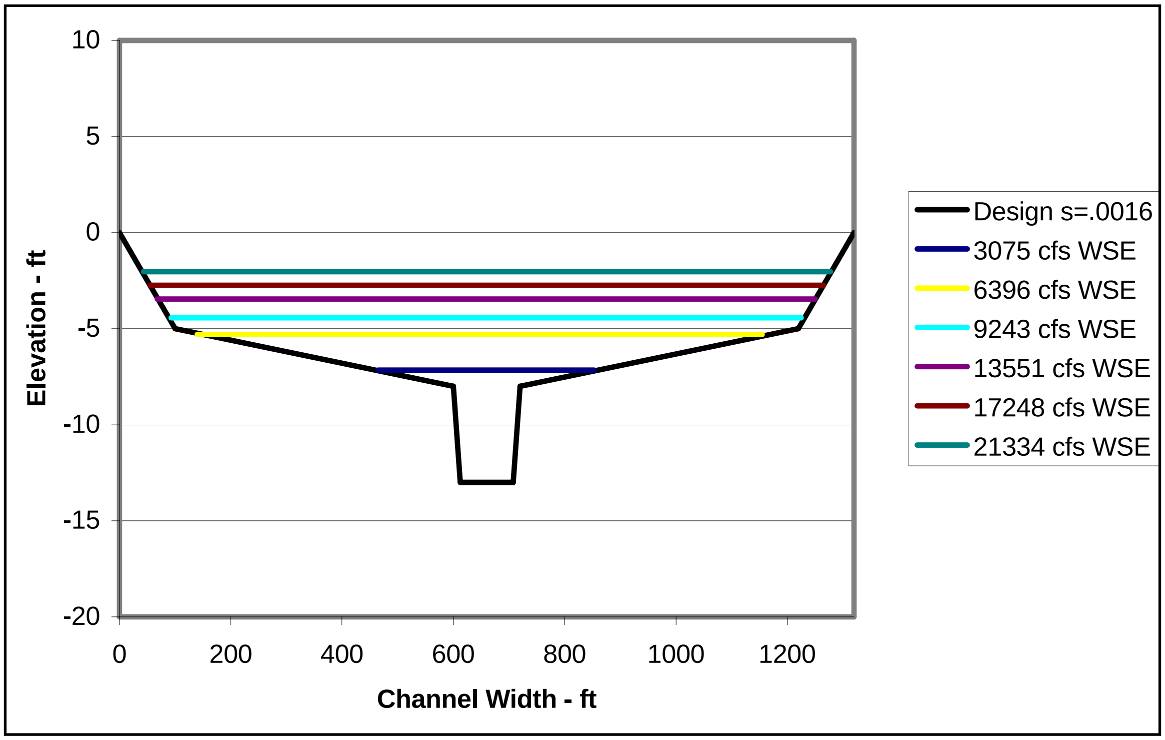

Figure 4. Water-surface elevations in design channel with a wide stream corridor

Computation of Sediment Rating Curves. Three sediment transport functions were selected for computing the transport capacity of each channel geometry: Meyer Peter Muller, Parker, and Schoklitsch. Each function is applicable to gravel bed streams, however, there is substantial uncertainty in these equations when applied to the more coarser cobble size fractions. The size distribution of the restoration reach sediments is given in Figure 5. The D50 of the distribution is 62 mm, with a D90 of 121 mm. Based on the D50, these bed sediments would be classified as very coarse gravel. The SAM sediment transport module computes the unit discharge of sediment and converts it to mass per unit time (tons/day). To facilitate comparison of the existing and design channel, the load data are presented as tons/day/unit width. Sediment rating curve comparison plots for each channel case are presented in Figures 6-11. Although the different transport functions indicate varying quantities of sediment load, the obvious trend is that the sediment transport capacity for the existing channel is higher, particularly for the 10-year and greater return flows (> 9,000 cfs). This indicates that the design channel will not be able to transport the entire incoming load and is, thus, potentially depositional.

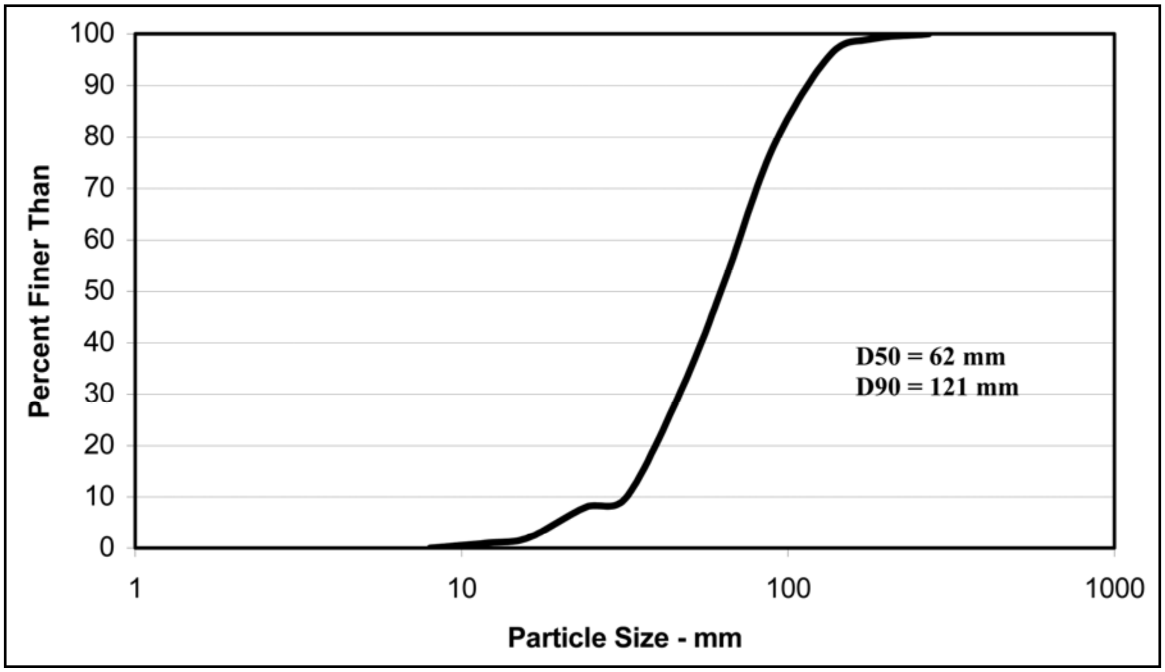

Figure 5. Particle size distribution of Truckee River bed sediments in restoration reach

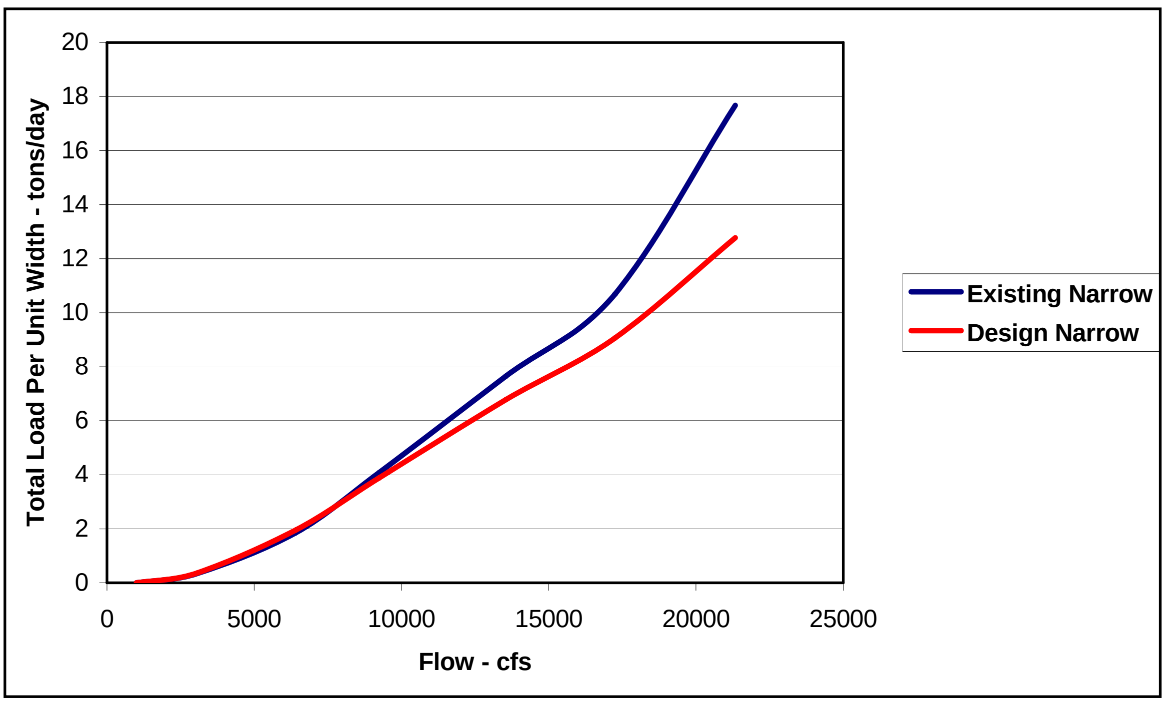

Figure 6. Sediment rating curve comparison for existing and design narrow stream corridor channels – Meyer Peter Muller function

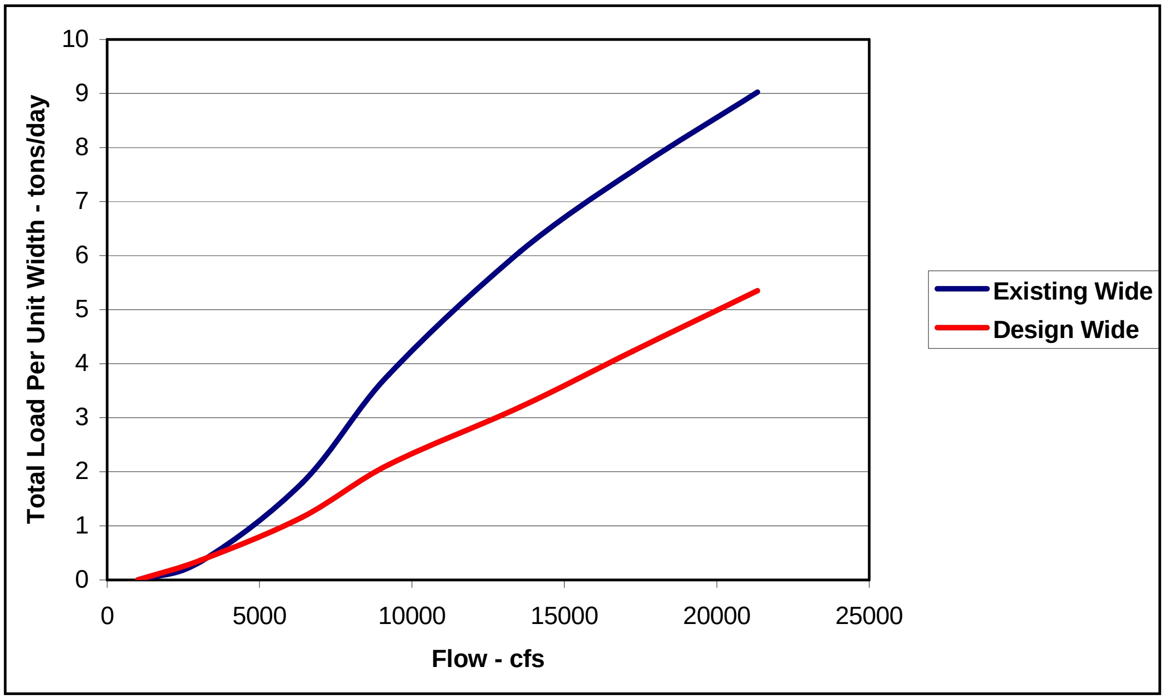

Figure 7. Sediment rating curve comparison for existing and design wide stream corridor channels – Meyer Peter Muller function

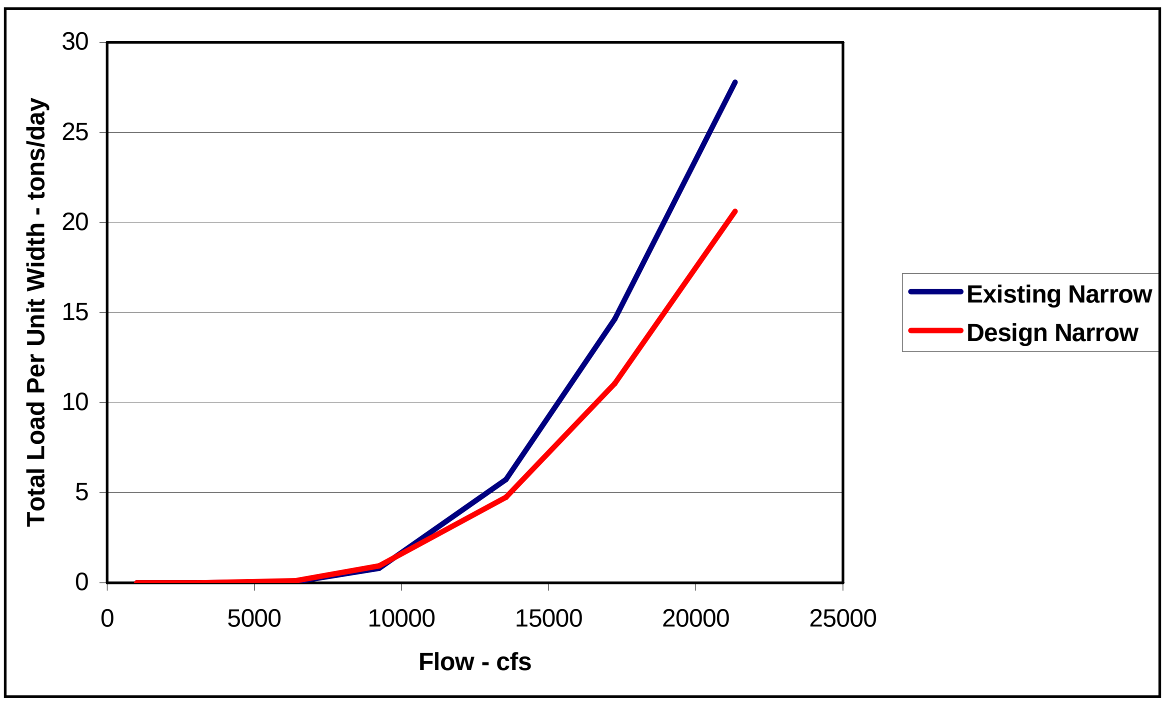

Figure 8. Sediment rating curve comparison for existing and design narrow stream corridor channels – Parker function

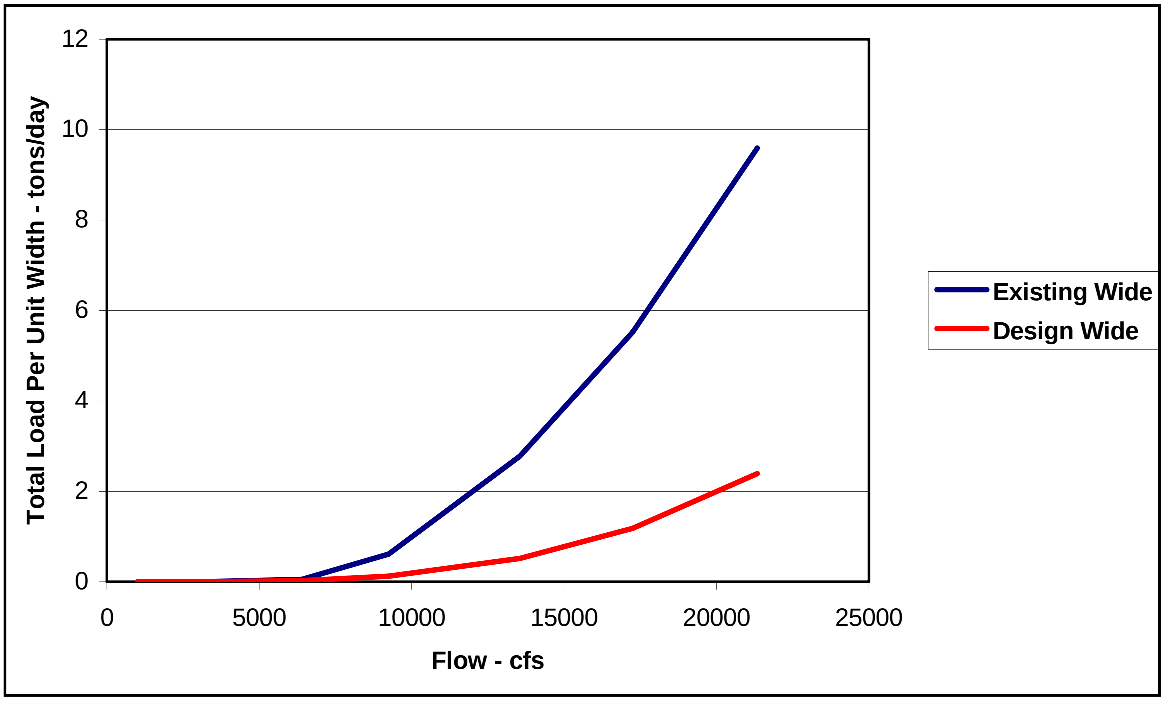

Figure 9. Sediment rating curve comparison for existing and design wide stream corridor channels – Parker function

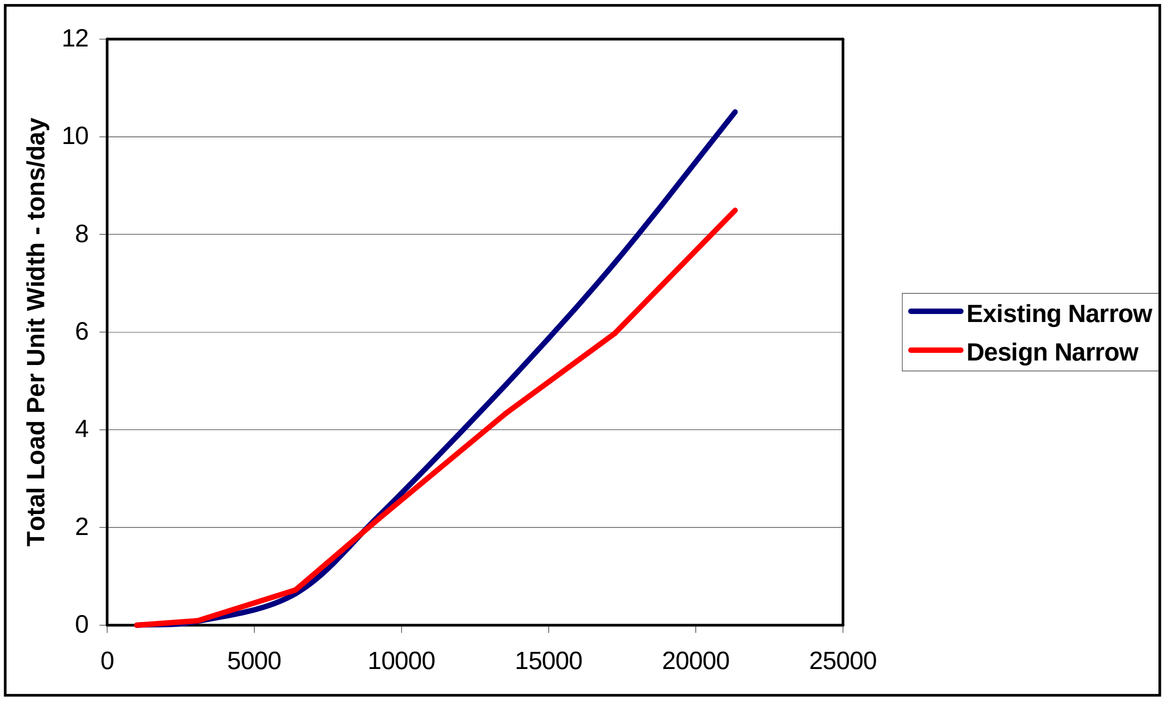

Figure 10. Sediment rating curve comparison for existing and design narrow stream corridor channels – Schoklitsch function

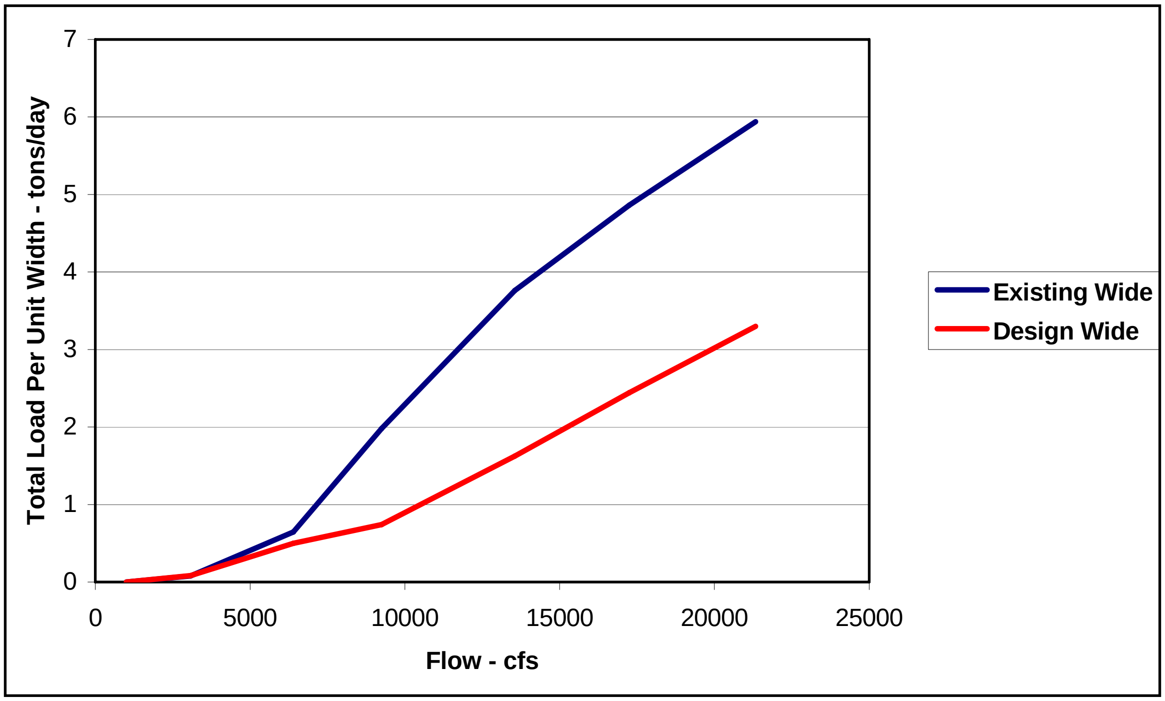

Figure 11. Sediment rating curve comparison for existing and design wide stream corridor channels – Schoklitsch function

Computation of Total Annual Sediment Yield. To compute the total annual sediment yield, you must integrate the sediment rating curve with the flow duration curve (discharge as a function of probability that the flow is equaled or exceeded) for the Truckee River. Figure 12 is the resulting flow duration curve. The SAM yield module was employed to compute the sediment yield for each sediment rating curve. A comparison of the total annual sediment load for each transport function is presented for the existing and design channel for the narrow and wide stream corridors (Tables 7 and 8). The difference in sediment yield indicates the potential for either deposition or degradation in the design channel. For this case, the design channel is depositional. The potential annual accumulation of sediment for the narrow channel ranges from a minimum of 43 tons of sediment (Parker transport function) to a maximum of 164 tons (Meyer Peter Muller transport function). The wide channel positive annual yield ranges from 58 tons (Parker transport function) to 354 tons (Meyer Peter Muller transport function).

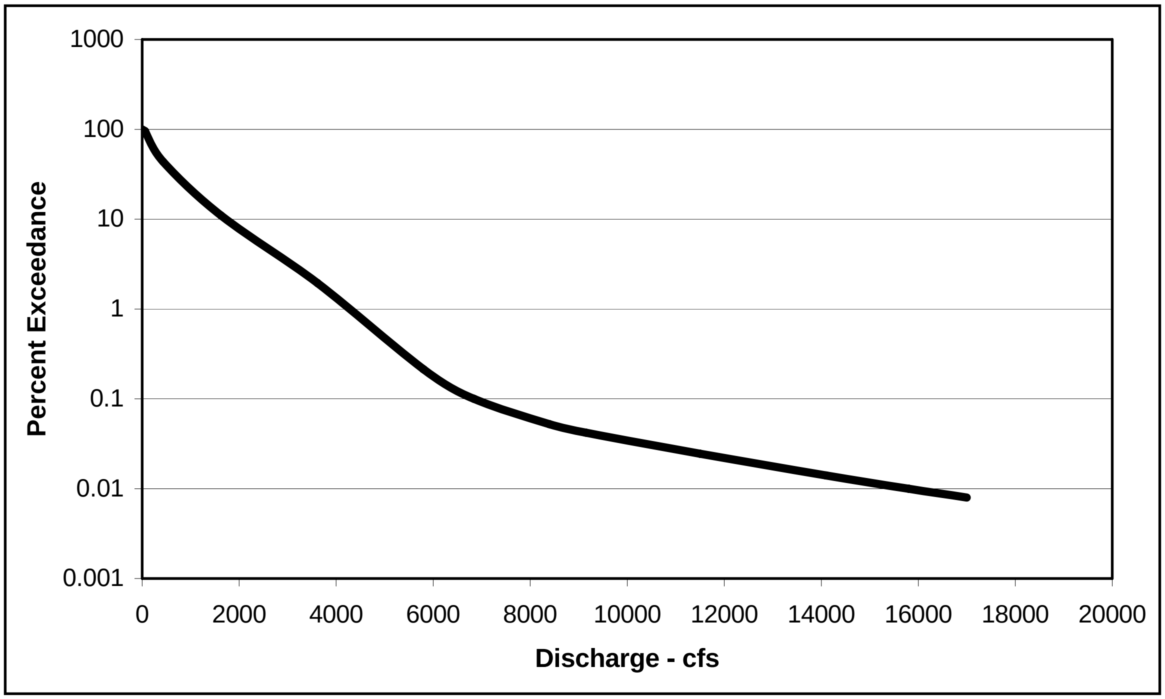

Figure 12. Flow duration curve for the Truckee River at Reno, NV

Table 7 **Annual Sediment Yield Comparison for Narrow Stream Corridor Channel**			
Transport Function	**Existing Channel, tons**	**Design Channel, tons**	**Difference, tons**
MPM	1,263	1,099	164
Parker	153	110	43
Schoklitsch	432	370	62
Note: Assumes existing and design movable bed width of 150 and 120 ft respectively.			

Table 8 **Annual Sediment Yield Comparison for Wide Stream Corridor Channel**			
Transport Function	**Existing Channel, tons**	**Design Channel, tons**	**Difference, tons**
MPM	1,210	816	394
Parker	73	15	58
Schoklitsch	401	263	138
Note: Assumes existing and design movable bed width of 150 and 120 ft respectively			

CONCLUSONS AND RECOMMENDATIONS: The SAM programs provide an efficient, reconnaissance level methodology to evaluate channel designs for potential stability problems. Although SAM does provide quantitative results, the true utility of the program is to evaluate the relative change between a base or existing condition and a plan or design condition. In the case of the Truckee River analysis, the Lane's balance proportionality function presented earlier indicated that the restoration design would probably be depositional, and the SAM analysis was in agreement with this. However, there is substantial uncertainty on predicting sediment transport of a very coarse

gravel and cobble bed stream like the Truckee River. Two of the functions used for this analysis were more appropriate for gravel beds only (Schoklitsch and Meyer Peter Muller), whereas Parker was more appropriate for armored gravel and cobble bed streams. The Parker transport function predicted lower transport rates than the other functions.

Although the design reach geometry can be classified as depositional by this analysis, this reach of the Truckee River may very well be supply limited by both the size of the bed materials and the degree of armoring that potentially exist on the bed. During a site visit, a number of bars located on the overbank were evident along the river that clearly indicated deposition of cobbles and gravel during a significant flow event. The elevation of these bars indicated a return event of at least 25 years was potentially responsible for the deposits.

The SAM programs are valuable tools for performing a quick reconnaissance level stability analysis of potential channel design alternatives. The SAM stable channel design program is normally used for this application, however, as indicated earlier in this CHETN, it is limited to a single gravel transport equation that is not applicable to the Truckee River bed sediment gradation. Additional research is needed to develop enhanced capability in SAM for evaluating gravel and cobble bed streams commonly found in Western high-elevation regions. Additionally, capability needs to be developed to evaluate compound channels designs for which the movable bed can be designated as a design variable.

POINT OF CONTACT: For additional information, contact Dr. Stephen Scott (601-634-2371, email: *Steve.H.Scott@erdc.usace.army.mil*) of the Coastal and Hydraulics Laboratory, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

This CHETN should be cited as follows:

> Scott, S. 2006. *Application of the SAM computer program for Truckee River stable channel analysis*. ERDC/CHL CHETN-VII-7, Vicksburg, MS: U.S. Army Engineer Research and Development Center. *http://chl.erdc.usace.army.mil/chetn/*.

REFERENCES

Lane, E. W. 1955. Design of stable channels. *Transactions of the American Society of Civil Engineers*. 120: 1234-1279.

U.S. Army Corps of Engineers. 2002. *Hydraulic design package for channels (SAM).* Users Manual. U.S. Army Engineer Research and Development Center.